Kawasaki Journal of Medical Welfare Vol. 15, No. 1, 2009 15–25

Original Paper

Current Status of House Fire Deaths among the Elderly

Fumio MORIYA*

(Accepted May 1, 2009)

Key words: house fire deaths, elderly individuals, carboxyhemoglobin, smoking, physical health

Abstract

The purpose of this study was to identify risk factors leading to house fire deaths among elderly individuals. Fire damage and autopsy results for 66 house fire victims (40 males, 26 females) aged 65 years or more were analyzed. Thirty-nine of these elderly individuals (26 males, 13 females) had lived alone, and 27 (14 males, 13 females) had lived with a spouse or family member. Mean CO-Hb saturation was 52.0% (range: 0–93.0%). In 53 cases, the buildings in which the deaths took place were one- or two-story detached wooden houses (27 victims living alone, 26 victims living with others) and in 9 cases they were wooden apartment buildings or wooden terraced housing (all the victims living alone). The cause of the fire, in 11 of the 27 cases in which it could be identified, was failure to extinguish burning cigarettes. Subjects' general health status related to performing everyday activities was determined in 60 cases. Thirteen of the elderly individuals were generally healthy, however the others had some type of impairment. The most common impairments were non-central nervous system gait disorders (18 cases), such as weakened leg muscles or joint disorders. Alcohol was detected in 5 cases. Therapeutic levels of prescribed psychotropic drugs were detected in 7 cases. Among elderly individuals who die in house fires, reduced motor functions and judgment ability caused by senescence are thought to be major risk factors that lead to a failure to act appropriately during fires, for example not escaping in time.

Introduction

As Japan makes the transition to an aging society, an increasingly large proportion of elderly individuals are living alone in rural areas. This situation has been caused by widespread social change, such as the concentration of young people in urban areas, combining with general factors that affect the elderly, such as losing a spouse. These changes have been accompanied by an increasing number of elderly individuals living alone becoming involved in various types of disasters, such as house fires or traffic accidents. To achieve a stable society for aged individuals, it is essential to construct disaster prevention measures based on analysis of the potential risk factors specific to their social environments and lifestyle patterns.

Bodies discovered at fire sites are usually subject to legal autopsy in order to determine the cause of death. In Japan, autopsies of fire victims are conducted in 300–400 cases annually, and many of these victims are elderly individuals over the age of 65 years. To identify the cause of death of fire victims both pathological findings and analytical toxicological findings on the amounts of carbon monoxide (CO) and

* Department of Nursing, Faculty of Health and Welfare, Kawasaki University of Medical Welfare, Kurashiki, Okayama 701-0193, Japan
E-Mail: moriyaf@mw.kawasaki-m.ac.jp

hydrogen cyanide (HCN), extremely toxic substances generated in fires that have invaded the body, are essential. Moriya et al. [1] previously investigated CO hemoglobin (CO-Hb) saturation in 47 fire victims in Okayama Prefecture, and found that: 1) the CO-Hb saturation was above 50% in 62% of house fire victims, which means that CO poisoning was the major cause of death; 2) there were no differences in CO-Hb saturation between age groups; and 3) there were no differences in distribution of CO-Hb saturation in drinkers and non-drinkers.

The present study was concerned with elderly house fire victims in Kochi Prefecture and the following were investigated: 1) the living environment and health status of these victims; 2) the building structure, cause of fire, and place and position of the body when it was discovered; and 3) CO-Hb saturation, methemoglobin (Met-Hb) contents, blood CN levels, blood alcohol levels, and concentrations of drugs in body tissues. The aim was to obtain basic data that could contribute to welfare policies for the aged instituted by national and local governments.

Materials and Methods

The subjects of this study were 110 autopsy cases of house fire victims in which the author performed toxicopathological analysis when he was at the Department of Legal Medicine, Kochi Medical School, Kochi University (August 1994–March 2008).

Information on the circumstances for the start of the fire and the victim's living environment, physical condition and medical history were provided by the investigative authorities based on informed consent from the authorities. Measurement of CO-Hb saturation was conducted using the spectrophotometric method of Ishizu et al. [3] or Katsumata et al. [4] for blood specimens obtained during the autopsies.

Blood CN and alcohol levels were measured using the headspace gas chromatographic methods of Moriya and Hashimoto [5] and Moriya and Ishizu [6].

Blood Met-Hb content was measured using the spectrophotometric method of Sato [7].

Quantitative and qualitative analyses were conducted for general drugs and chemicals using Moriya and Hashimoto's [8] liquid-liquid extraction-gas chromatographic and gas chromatographic/mass spectrometric methods for blood samples after screening tests of urine samples had been conducted using Triage^{TM} DOA.

Statistical analysis was performed using the t-test. Differences were considered to be significant at $p<0.05$.

Results and Discussion

1. Proportion of Elderly among Fire Victims, Living Environment, and CO-Hb Saturation

Among 110 fire fatalities, 66 (60.0%, males 40, females 26) were aged 65 years or older. This proportion of elderly victims was larger than at the time of the previous study in Okayama [1]. The largest age group was 75–79 years (16 cases). Among elderly fire victims, 39 had been living alone (59.1%, male 26, female 13), and 27 had been living with a spouse or family member (40.9%, male 14, female 13). A greater proportion of individuals therefore had been living alone (Fig. 1) at the time of death. The present data show that efforts to prevent fire damage among individuals living alone are urgently needed. One reason for the smaller proportion of elderly women than men may be that, in general, women are more accustomed to housework from an early age and adopt more cautious behaviors in handling fire. However, more research is necessary to ascertain the true nature and causes of this discrepancy.

The relationship between the age of the fire victims and CO-Hb saturation is shown in Fig. 2. CO-Hb saturation is extremely important in determining the cause of death and estimating the circumstances

during the fire, such as the time from the start of the fire until death. Teige et al. [10] reported that CO poisoning may be considered the main cause of death in cases when CO-Hb saturation exceeds 50%; the author also believes that such a judgment can be made from the various autopsy findings in fire victims that he has handled.

The mean CO-Hb saturation recorded in elderly fire victims, 52.0% (range: 0–93.0%), was marginally higher than the mean recorded in fire victims under the age of 65 (42.5%, range: 1.0–93.0%), however the difference between the two groups was not considered significant. These results are similar to findings in the earlier study conducted by the author [1]. However, if the mean CO-Hb saturation for elderly individuals living alone and those living with others is looked at separately, the following figures are revealed: 46.0% (range: 0–89.0%) in individuals living alone and 60.7% (range: 1.0–93.0%) in those living with others. The CO-Hb saturation was thus significantly lower in individuals living alone than in individuals living with others ($p<0.05$). Compared with elderly people living with others, elderly people living alone have more occasion to deal directly with fire, such as when cooking, and the lower CO-Hb saturation in victims living alone may suggest in a greater proportion of these cases, the body catches fire due to negligence and they die from burns without inhaling a sufficient amount of fire gases.

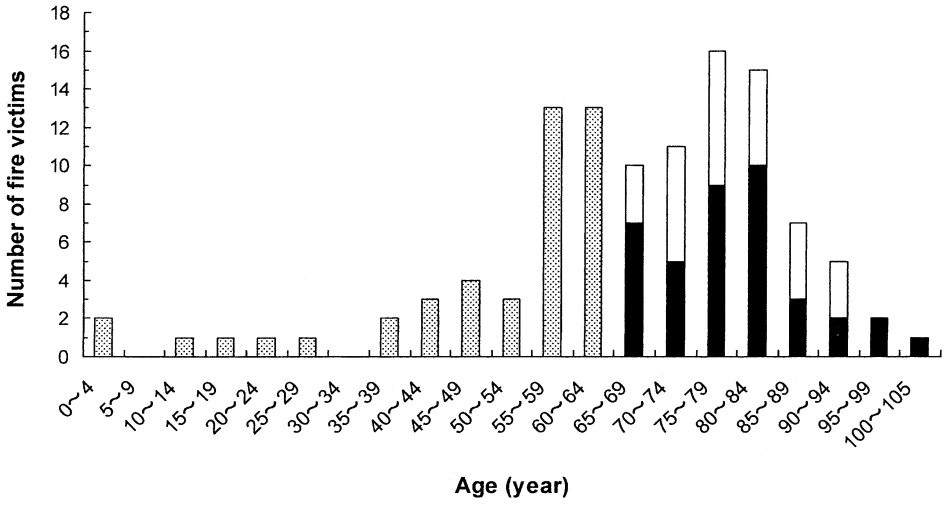

Fig. 1 Ages of 110 house fire victims.
■: elderly living alone; □: elderly living with others.

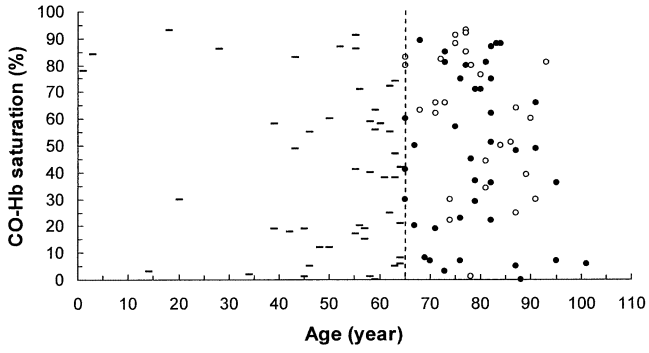

Fig. 2 Relationship between CO-Hb saturation and age in house fire victims.
●: elderly living alone; ○: elderly living with others.

2. Season and Time of Day of the Occurrence of Fire

Looking at the number of fires involving elderly individuals by season, reveals that the greatest number (33, 50.0%) occur during the months of January to March, when heating is most needed. Of the 39 individuals living alone at the time of their death, 20 (51.3%) died during these months compared with 13 of the 27 (48.1%) living with others who died during the same period. The number of victims from October to March was 50 (75.8%), 29 who lived alone (74.4% of those who lived alone) and 21 who lived with others (77.8% of those who lived with others). It can be also seen from Fig. 3 that fire damage was clearly seasonally dependent both in those who lived alone and those who lived with others. Among the elderly who lived alone, 8 cases of fire damage (20.5% of those living alone) occurred in the months of April to June. As mentioned in the preceding section, it is very likely that this reflects the fact that individuals living alone have more occasion to handle fire themselves. Individuals living alone need to exercise caution with fire year-round.

As shown in Fig. 4, the time of day when the fires occurred was from evening to early morning in about 70% of all cases; however, as a high percentage of elderly spend many hours at home, they also need to exercise caution with fire during the day.

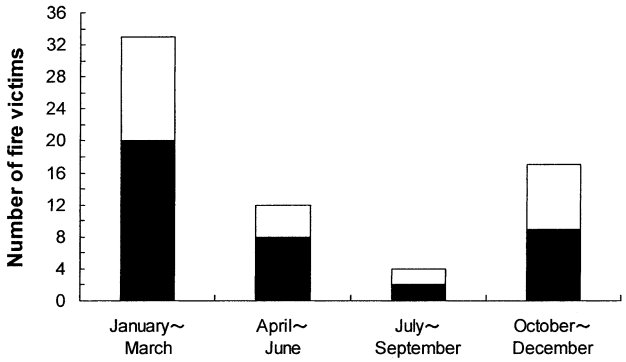

Fig. 3 Number of elderly house fire victims according to month of death.
■: elderly living alone; □: elderly living with others.

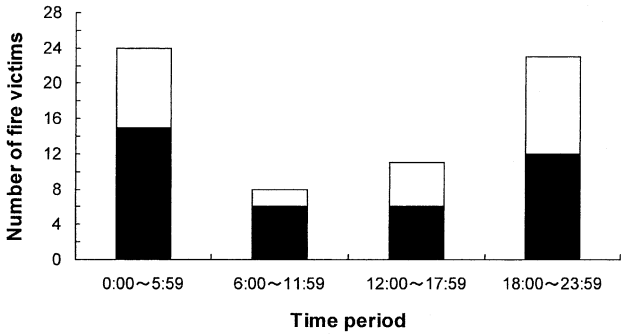

Fig. 4 Number of elderly house fire victims according to time period.
■: elderly living alone; □: elderly living with others.

3. Relationship between CO-Hb Saturation, Blood CN Levels, and Met-Hb Content

The cause of death in individuals discovered at fire sites is often determined from the extent of burn injury, CO-Hb saturation, and whether there was oxygen starvation. However, during fires, CO and various other toxic gases are emitted. In modern houses, the materials used contain much nitrogen, such as in

polyurethane and polyacrylonitrile, from which large amounts of HCN are produced when burned [10–12]. CN is a strong inhibitor of mitochondrial cytochrome oxidase, and even low concentrations evoke very strong toxic symptoms [13]. Blood CN levels in fire victims sometimes exceed toxic or fatal levels (3 μg/ml), which are seen when CN compounds are consumed excessively [14, 15]. Thus, it is important to measure blood CN levels in fire victims [16]. However, CN is very unstable in biological specimens due to its physicochemical properties and metabolic characteristics [5, 17]. In burned bodies that are left at room temperature, it would be extremely difficult to detect CN from blood if more than 3 days have passed after death [2]. Moriya and Hashimoto [18] have shown that disappearance of CN from blood proceeds with a first-order process, with a mean rate constant of 0.046/h. In the elderly fire victims that were the subjects in this study, 6–36 hours had passed after death, and the rate of decrease in blood CN level is thought to have been 20–80%. The CN blood levels in the elderly fire victims (n=27) in whom the author conducted CN analysis showed a wide range (0.07–6.84 μg/ml; mean, 2.02 μg/ml), and although blood CN levels decrease after death, amounts exceeding 3 μg/ml were detected in several cases. Looking separately at those who lived alone and those who lived with others, CN levels were 0.13–5.16 μg/ml (mean, 1.82 μg/ml) in those who lived alone (n=17) and 0.07–6.84 μg/ml (mean, 2.36 μg/ml) in those who lived with others (n=10). No significant differences were observed. As shown in Fig. 5, victims showing high blood CN levels (3 μg/ml or more) also tended to have high CO-Hb saturation. This suggests that in fire environments in which large amounts of HCN are emitted, large amounts of CO may also be emitted.

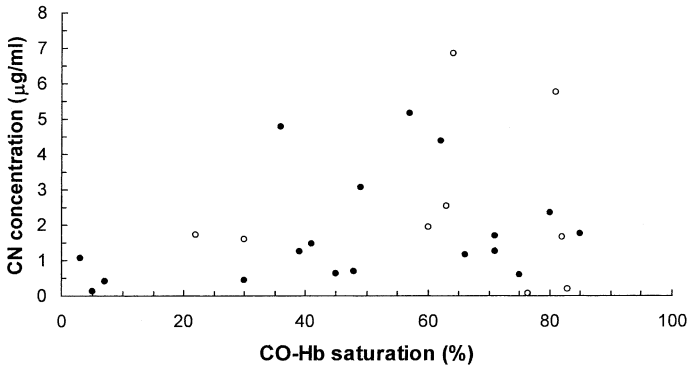

Fig. 5 Relationship between CO-Hb saturation and CN concentrations in elderly house fire victims.
●: elderly living alone; ○: elderly living with others.

It is possible that Met-Hb is formed, although in very small amounts, with the inhalation of fire gases [19]. The Met-Hb content measured in elderly victims (n=20) was 0–6.6% (mean 2.2%). It was 0–6.6% (mean 2.6%) in the group that lived alone (n=11) and 0.1–5.3% (mean 1.8%) in the group that lived with others (n=9). As shown in Figs. 6 and 7, no large differences were seen between the groups in the relationship between Met-Hb content and CO-Hb saturation or in Met-Hb content and blood CN levels.

It is important that Met-Hb content be measured together with CO-Hb saturation when conducting an evaluation of toxicity of the detected CN levels. CN quickly binds with Met-Hb in blood, so that even if it reaches blood concentrations that are generally considered to be fatal, if Met-Hb is present even in small amounts it will bind with the CN and alter it's toxicity. Thus, it should be interpreted as not showing toxicity [2]. CN at about 2 μg/ml is trapped with a Met-Hb content of 1% [2], and so only a slight increase in Met-Hb can bring free CN levels from fatal levels to nontoxic levels. Therefore, it is necessary to consider CN poisoning only when Met-Hb is not detected, CO-Hb saturation is low, and blood CN level is high. Only one such case was seen in the group of victims living alone in which CN analysis was conducted.

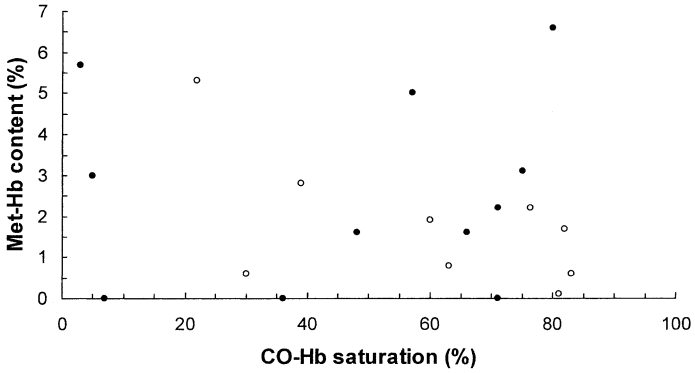

Fig. 6 Relationship between CO-Hb saturation and Met-Hb content in elderly house fire victims.
●: elderly living alone; ○: elderly living with others.

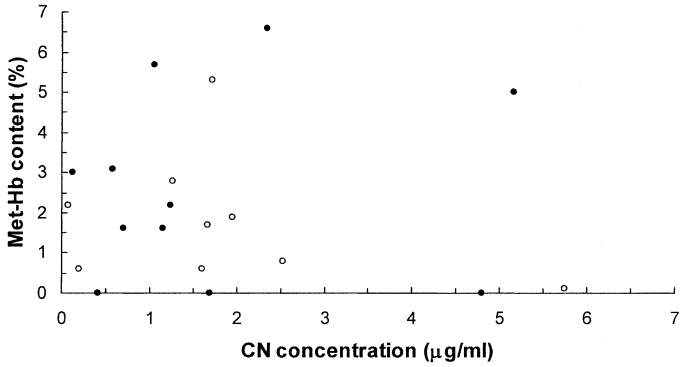

Fig. 7 Relationship between CN concentrations and Met-Hb content in elderly house fire victims.
●: elderly living alone; ○: elderly living with others.

4. House Structure

The living environments of the elderly fire victims are shown in Fig. 8. The majority of both individuals living alone and individuals living with others lived in one- or two-story detached wooden houses. All of the fire victims in wooden apartment buildings or wooden terraced housing were elderly people who lived alone.

From the large number of fire victims, it can be said that while it is necessary to urge careful attention to fire among elderly individuals and their families who live in detached houses, it is also necessary to understand the living situations of elderly individuals who live alone in aging wooden apartment buildings or terraced housing and strengthen fire prevention measures in these buildings.

5. Place and Position of Body at Time of Discovery

As shown in Fig. 9, bodies were most commonly discovered in the bedroom (26 cases, 39.4%). Taken together with the time the fire occurred, it may be concluded that active promotion of behaviors to prevent accidental fires during sleep, for both elderly people living alone and living with others, is needed.

The body was found in the living room or other common rooms in 18 cases (27.3%). The body was found in or near the entryway in 15 cases (22.7%), of which 11 were individuals living alone. It could be inferred that the majority of these victims had noticed the fire and tried to escape outdoors, but were unable to vacate the house in time and burned to death. Government efforts are needed to provide housing that is user-friendly for elderly individuals, and to evaluate the safety of existing housing. No special relationship

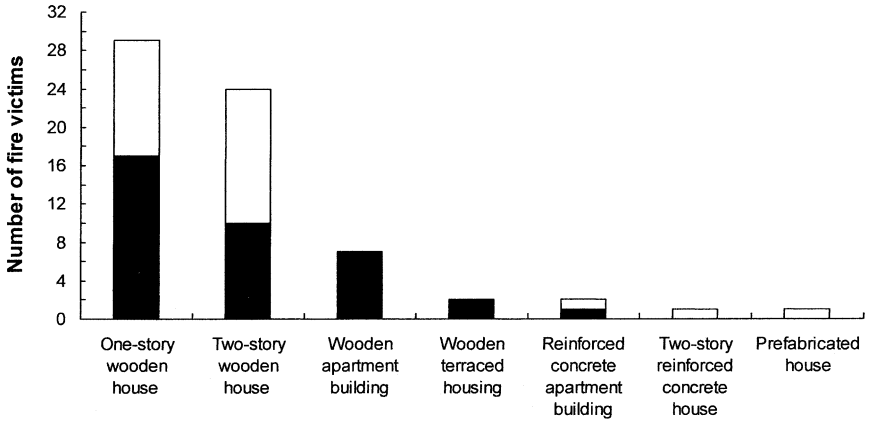

Fig. 8 Dwellings burnt in fires involving elderly individuals.
■: elderly living alone; □: elderly living with others.

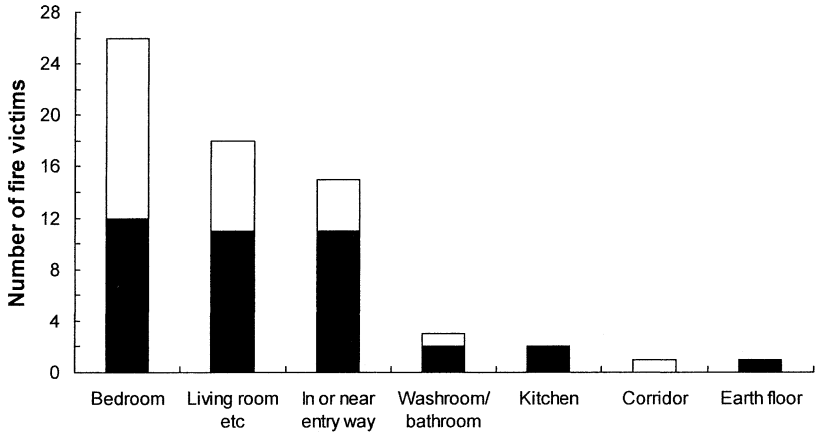

Fig. 9 Locations where bodies of elderly individuals were found after house fires.
■: elderly living alone; □: elderly living with others.

was noted between the place the body was discovered and CO-Hb saturation, however in cases that showed low CO-Hb saturation (<20%) there is a high possibility of death from burns due to accidental outbreak of fire during regular activities.

The position of the body at the time it was found was supine in the greatest number of cases, 39 (24 living alone, 15 living with others), followed by prone position in 15 cases (6 living alone, 9 living with others), side lying position in 11 cases (8 living alone, 3 living with others) and a sitting position in 1 (living alone). No particular relationship was noted between body position at time of discovery and the place the body was discovered.

6. Source and Cause of Fire

The location where the fire started could be identified in 45 of the 66 cases. A bedroom or living room accounted for three-quarters of all cases: 18 victims living alone, and 15 victims living with others. Other locations the fire started were the kitchen in 6 cases (3 each for victims living alone and living with others), fire spreading from a neighboring house in 4 cases (2 each for victims living alone and living with others), and 2 in the bathroom (victims living with others) (Fig. 10).

Figure 11 shows the causes of the fires. The cause of the fire could be identified in 27 cases, of which

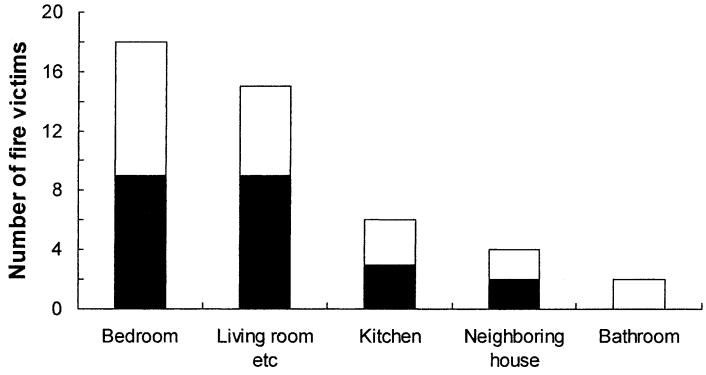

Fig. 10 Origins of fatal house fires involving elderly individuals.
■: elderly living alone; □: elderly living with others.

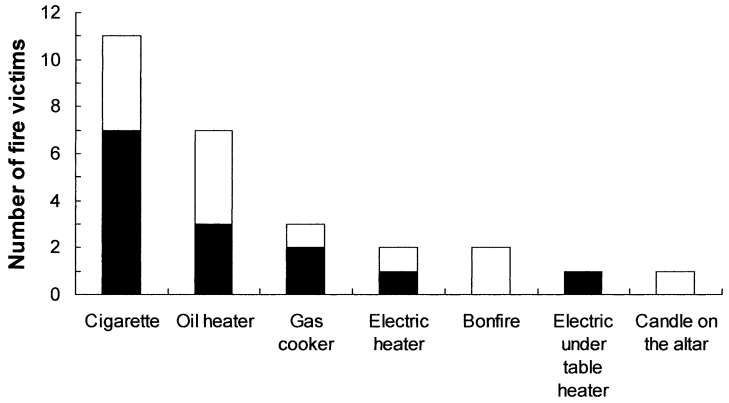

Fig. 11 Causes of fatal house fires involving elderly individuals.
■: elderly living alone; □: elderly living with others.

11 were judged from investigative information and analysis of nicotine and cotinine in the blood to be failure to extinguish burning cigarettes. In 7 of these cases the victim lived alone, and in 4 the victim lived with others. Considering that there were a fair number of cases for which there was little investigative information and nicotine and cotinine analysis could not be performed, and that the fire started in a bedroom or living room in the majority of cases, it seems highly likely that the real number of cases of failure to extinguish burning cigarettes was higher than the identified number. The risk of fires caused by not putting out cigarettes has been pointed out before, however it may be necessary to conduct frequent and repeated educational campaigns for the elderly.

7. Health Status

The health status of the fire victims could be determined in 60 of the 66 cases based on investigative information on physical status and medical history, and autopsy findings. Figure 12 summarizes the diseases or conditions that should most be considered for each case. Thirteen of the elderly (21.7%, 8 living alone, 5 living with others) were in generally good health without any specific disability. The most common impairment was non-central nervous system gait disorders, such as weak leg muscles or joint disorder, in 18 cases (30.0%, 12 living alone, 6 living with others), followed by dementia in 8 cases (13.3%, 4 each living alone and living with others), sequelae of cerebral infarction in 6 cases (10.0%, 3 each living alone and living with others), and 15 other cases. Many of the elderly living alone had motor function impairment of the legs of varying severity, unrelated to central nervous system diseases, such as cerebral

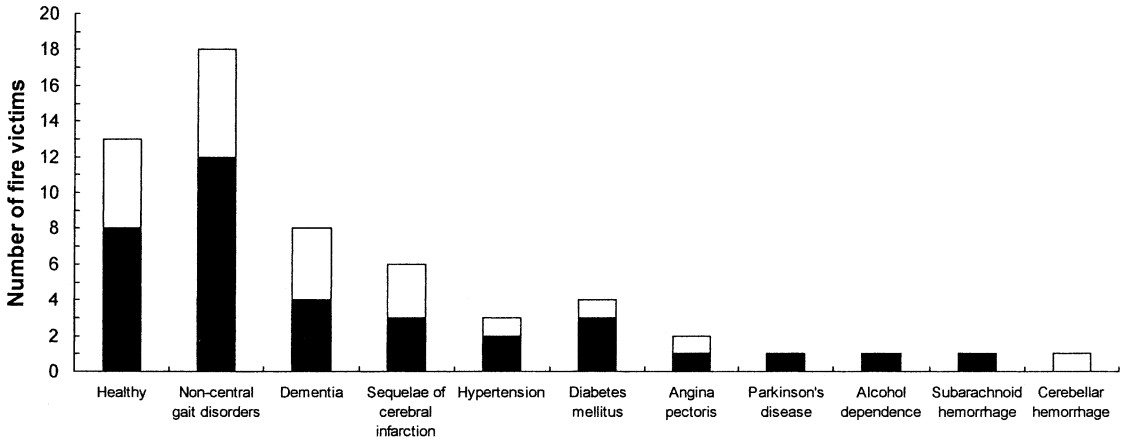

Fig. 12 Physical conditions of elderly house fire victims.
■: elderly living alone; □: elderly living with others.

infarction. Welfare personnel need to renew their recognition that this is a major risk factor for slow escape during fires. In addition, among the elderly, the ability to make judgments decreases together with motor function, and this increases the risk of being caught in a fire. Moreover, elderly people with dementia or sequelae of cerebral infarction who live alone, respectively, both accounted for about 10% of the fire victims. This is something that must be considered in developing welfare measures to prevent fire injury in elderly individuals. Impaired consciousness and behavioral disorders resulting from subarachnoid hemorrhage or cerebellar hemorrhage was assumed to be the cause of the fire in two cases. It should be noted in elderly individuals that intracranial hemorrhage is in some cases an indirect cause of fire.

8. Alcohol and Drug Ingestion

Analysis of alcohol was possible in 108 of 110 cases. Among fire victims aged 20–64 years, alcohol levels of 0.2–4.1 mg/ml (mean: 1.6 mg/ml) were detected in the blood in 17 of 42 cases (40.5%), and accidental fire during intoxication was conspicuous. The greatest number of drinkers was among individuals in their 50s (8 cases). Alcohol from drinking was detected in only 5 of the 66 elderly individuals aged 65 years or older (7.6%, 3 living alone, 2 living with others). The blood-alcohol levels in these cases were 0.3–1.3 mg/ml (mean: 0.9 mg/ml). It is not known whether the low number of drinkers among the elderly fire victims was simply due to a decreased drinking rate with age, or to health or other problems.

Analysis for drugs was possible in all cases. Psychotropic or other drugs were detected in 9 of 44 cases (20.5%) in the young group and 7 of 66 cases (10.6%, all living alone) in the elderly group. Methamphetamine levels of 0.82 μg/ml were detected in the blood in 1 case in the young group, and abnormal behavior was suspected to be related to the cause of the fire. In other cases, drugs were administered mainly for the purposes of inducing sleep or sedation, and there was no evidence of an abnormal intake that would lead directly to accidental fire.

Based on the results of this study, there is little association between alcohol or drug intake and fire injury in elderly individuals.

Conclusions

This study demonstrated the following with regard to accidental fire deaths of elderly individuals living alone.

1. In a large proportion of cases, the cause of the fire is mismanagement of burning cigarettes or heat appliances in a bedroom or living room.
2. In a large number of cases, the dwelling is an aging and flammable wooden detached house, or wooden apartment building or terraced housing.
3. Motor function impairment of the legs or decreased ability to make judgments are among the main factors leading to the failure to act appropriately, such as being slow to escape during a fire.
4. The possibility of alcohol and drug intake being a risk factor is low.

The results of this study may serve as valuable basic data that can be used in investigations of welfare policies to prevent fire injury among elderly individuals in the future.

Acknowledgement

Part of this study was funded by a 2003 research grant from The Univers Foundation.

References

1. Moriya F, Hashimoto Y and Nanikawa R: Carboxyhemoglobin concentrations in victims burned to death. *Res Pract Forens Med* 33: 137–140, 1990 (in Japanese with English abstract).
2. Moriya F and Hashimoto Y: Potential for error when assessing blood cyanide concentrations in fire victims. *J Forensic Sci* 46: 1421–1425, 2001.
3. Ishizu H, Ameno S, Yamamoto Y, Okamura K and Shogano N: A simple spectrophotometric method for CO-Hb determination in blood and its application in legal medicine. *Act Crim Japon* 48: 187–196, 1982 (in Japanese with English abstract).
4. Katsumata Y, Aoki M, Sato K, Suzuki O, Oya M and Yada S: A simple spectrophotometry for determination of carboxyhemoglobin in blood. *J Forensic Sci* 27: 928–34, 1982.
5. Moriya F and Hashimoto Y: Stability of cyanide in blood. *Jpn J Forensic Toxicol* 18: 49–58, 2000.
6. Moriya F and Ishizu H: Can microorganisms produce alcohol in body cavities of a living person? A case report. *J Forensic Sci* 39: 883–888, 1994.
7. Sato K: A method for determination of methemoglobin in blood containing carboxyhemoglobin. *Jpn J Legal Med* 37: 133–144, 1983 (in Japanese with English abstract).
8. Moriya F and Hashimoto Y: Medicolegal implications of drugs and chemicals detected in intracranial hematomas. *J Forensic Sci* 43: 980–984, 1998.
9. Teige B, Lundevall J and Fleischer E: Carboxyheamoglobin concentrations in fire victims and cases of fatal carbon monoxide poisoning. *Z Rechtsmed* 80: 17–21, 1977.
10. Woolley WD: Nitrogen-containing products from the thermal decomposition of flexible polyurethane foams. *Br Polymer J* 4: 27–43, 1972.
11. Sumi K and Tsuchiya Y: Combustion products of polymeric materials containing nitrogen in their chemical structure. *J Fire Flammability* 4: 15–22, 1973.
12. Napier DN: Hazardous materials and the gases they produce. *Med Sci Law* 17: 83–90, 1977.
13. Smith RP: Toxic responses of the blood, in *Casarett and Doull's Toxicology: The Basic Science of Poisons*, edited by Klaassen CD, 5th edition, New York, McGraw-Hill, 1996, pp 335–354.
14. Wetherell HR: The occurrence of cyanide in the blood of fire victims. *J Forensic Sci* 11: 167–173, 1966.
15. Anderson RA and Harland WA: Fire deaths in the Glasgow area: Ⅲ the role of hydrogen cyanide. *Med Sci Law* 22: 35–40, 1982.
16. Shiono H, Maseda C, Akane A and Matsubara K: The blood cyanide levels in fire victims: rapid and sensitive

quantitation of cyanide in blood and its application to autopsy cases. *Act Crim Japon* 57: 73–79, 1991 (in Japanese with English abstract).

17. Bonnichsen R and Maehly AC: Poisoning by volatile compounds: Ⅲ hydrocyanic acid. *J Forensic Sci* 11: 516–528, 1966.
18. Moriya F and Hashimoto Y: Chemical factors affecting the interpretation of blood cyanide concentrations in fire victims. *Leg Med* 5, s113–s117, 2003.
19. Katsumata Y, Aoki M, Oya M, Suzuki O and Yada S: Simultaneous determination of carboxyhemoglobin and methemoglobin in victims of carbon monoxide poisoning. *J Forensic Sci* 25: 546–549, 1980.